NPS Investigates Renewable Powered Heating Ventilation & Cooling with Thermal Storage

ESTEP Project Seeks to Lower Facility Operating Costs & Increase Energy Security

WITH RESOURCES PROVIDED by the Energy Systems Technology and Evaluation Program (ESTEP), researchers at the Naval Postgraduate School (NPS) have investigated and installed a thermal energy system to provide supplemental power for facility heating and cooling systems.

Background

Using renewable energy reduces the Navy's dependence on fossil fuels and traditional sources of electricity. Renewable energy is often fed into the commercial energy grid to offset costs. But if the grid fails, access to these renewable resources is lost. Additionally, while current state laws often stipulate that a utility must sell electricity from renewable sources at cost, this situation is unlikely to continue. Rather, it is likely that renewable resources will start to be treated like more traditional sources of energy—meaning that power plants sell energy at a certain price to the utility and the utility resells it at a higher price to consumers. With these factors in mind, using renewable energy 'behind the meter' is a better way of reducing costs.

From an energy security standpoint, being energy self-sufficient when the grid fails is essential for U.S. Navy facilities. At present, a fuel farm and some form of backup generation is used for this purpose.

NPS and other researchers are investigating ways to enhance the performance and longevity of microgrids, battery storage and backup generators to allow for longer periods of off-grid operation. Allowing access to renewable resources when the grid fails could extend the length of time that a generator's fuel farm can last.

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Using backup generators and batteries to allow for off-grid operation assumes that the best methods for storing and transporting energy utilize hydrocarbons and electricity. But at the NPS in Monterey, California, researchers Anthony Gannon and Anthony Pollman are questioning this basic assumption. Through their ESTEP project, they have created an energy storage system designed specifically for heating and cooling needs.

In a paper written about the project for an American Society of Mechanical Engineers conference, Gannon and

Pollman state, "To effectively start to tackle the problem of energy generation, storage and transport, the end application of the energy should be used as the starting point in designing systems and making best use of the vast array of new technologies becoming available."

The end application that often uses the most energy at a Navy facility is heating, cooling and ventilation, which incorporates building heating and cooling, hot water heating, and data center cooling. In order to better store energy for these systems, the researchers designed and constructed a thermal energy storage system at the NPS Turbopropulsion Laboratory.

In the front of this unit are the thermal bricks used to store heat. This small free-standing unit, suitable for a single room, was used to develop control strategies and test the program being used before moving onto the control of a larger unit.

Thermal energy refers to the energy stored in a substance due to its temperature. This form of energy storage is safer, more economical, and has a longer lifecycle than battery storage systems.

Hot Thermal Storage

In times of excess generation or cheap electricity being available, this energy can be stored, often in a water tank. Another common way of storing energy thermally is with the use of ceramic bricks—the approach chosen by NPS researchers. These bricks are heated using an electrical element and stored in a specially designed unit that allows them to maintain heat for up to three

The large installed thermal storage unit weighs approximately 2,100 pounds, and can store 120 kilowatt hours (kWh) or 426,500 British Thermal Units of heat. It has one moving part (the fan) which blows air through the unit and is therefore very simple to operate and maintain.

The ice storage tank used in the system has a 144 kWh of thermal storage capacity. The mixture pumped through the tank is 75 percent water and 25 percent propylene glycol. Propylene was chosen over ethylene glycol as it is suitable for food grade applications and is not harmful to humans if accidentally ingested in moderate amounts. Propylene has a slightly higher viscosity, but this slight loss in system efficiency becomes less of an issue when a renewable power source is used.

The complete cooling system includes a variable speed chiller and pump. This system will be used to cool a large compressor's exhaust air before it enters a storage tank. Control signals can be sent to the chiller for it to operate between 20 to 100 percent of its rated capacity. The fluid pump can run separately from the chiller to circulate the chilled mixture through whatever device requires cooling.

days. When a space must be heated, air is blown through the bricks and exhausted into the space. The heating elements are controlled by solid state silicone controlled rectifiers which can be instantly programmed to adjust the amount of power being sent to the heating elements.

This technology can also be used in parallel with a normal forced air heating system and has the advantage of being less complicated than using a tank filled with liquid.

Cold Thermal Storage

In the case of cooling, there are a number of commercially available systems that make use of the heat of formation that is required to freeze and melt ice. A cold solution of water and antifreeze is circulated through tubes immersed in a tank that contains water. Water then freezes and accumulates on the outside of the tubes. When cooling is required, hot water from a cooling system can be deposited into a thermal storage tank, which then melts the ice and cools the solution for recirculation through the system.

Integrating the System

While both the cooling and heating systems installed for this project are based on commercially available components, the ability to effectively integrate these components into a renewably powered system required some modifications.

It was also imperative that the devices be controllable locally so that the demand from the systems could be closely matched with the available renewable supply. The development of this control system was quite challenging.

The microgrid used for this ESTEP project. It is essential that communication and data be extracted from such systems to obtain the most value from them.

The main issue involved with creating this control system was obtaining data from the renewable resources on how much power is available.

Challenges

Because the communication and control standards vary greatly among industries, the project team created and implemented a control algorithm to send commands out to the system.

The main issue involved with creating this control system was obtaining data from the renewable resources on how much power is available. To accomplish this task, the team connected the local microgrid to a control computer to gather available incoming power data, after which the heating or cooling system power was adjusted accordingly.

At the outset, the researchers assumed that the main challenge would be the development of the control system. However, just as challenging was communicating with manufacturers regarding the concept of matching demand to available supply. Microgrid systems are designed on an assumed usage of a certain number of Joules or kilowatt hours per day. Researchers discovered resistance to developing a system where electrical demand is matched to the available supply and energy stored in other forms.

The varying communication and control standards among industries made it challenging to integrate components and ensure that products from different industries were compatible. Therefore custom components had to be ordered for both the heating and chilling systems.

Conclusions

The construction of these demonstration systems has proven invaluable—most importantly because it has proven that systems designed with the end use in mind are possible.

The Basics About the Energy Systems Technology and Evaluation Program

ESTEP FOCUSES ON energy technologies that reduce costs, increase energy security, and ultimately increase the reach and persistence of the warfighter. ESTEP seeks to identify viable emerging energy technologies, obtained for the most part from open-market sources and in-house government demonstrations. Technologies identified as promising by ESTEP will be demonstrated, and data will be collected to evaluate the performance and reliability of selected technologies under various environmental and operating conditions. The entire program encompasses the following investment areas:

- Cyber and Energy Management for Information Systems
- Power and Energy Components
- Power and Energy Production/Efficiency

Established in fiscal year 2013, ESTEP casts a wide net across the Department of the Navy, academia, and private industry to investigate and test emerging energy technologies at Navy and Marine Corps installations. At present, ESTEP conducts nearly two dozen in-house government energy projects, ranging from energy management to alternative energy and storage technologies. Additionally, an ESTEP Broad Agency Announcement has awarded several contracts to industry in those same energy areas.

In addition to testing and evaluating performance and reliability of energy technologies, ESTEP provides mentoring (via on-the-job training and education of interns) and other workforce development opportunities by partnering with the Troops-to-Engineers program for veterans at San Diego State University and other universities. Workforce and professional development are key components of ESTEP and integral to the success of executing and transitioning energy technology projects at naval facilities.

ONR provides funding and oversight for ESTEP, and program management is being handled by the Space and Naval Warfare Systems Center Pacific. The Naval Facilities Engineering and Expeditionary Warfare Center and the NPS are executing selected research projects, and every project plans to involve at least one veteran intern utilizing an ESTEP grant to academic institutions.

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Ultimately, this system could serve as a model for forward operating bases and remote stations. The thermal storage makes the system grid-independent, and helps to extend battery life. In addition, commercial equipment can be readily purchased, transferred to, and set up in international areas.

While the construction of this system will reduce the cost of energy at NPS, these facilities are also available for other U.S. Navy and Department of Defense personnel to inspect and possibly adapt for their own purposes. These facilities have also provided enormous educational opportunities for NPS postgraduate students as they advance their field of knowledge.

For More Information

Three dissertations have been completed by students working on this project. These documents are available on the NPS Thesis and Dissertation Collection website:

1. "Initial investigation of a novel thermal storage concept as part of a renewable energy system," by L.M. Olsen at http://hdl.handle.net/10945/34716.
2. "Hot thermal storage in a variable power, renewable energy system," by T.D. Hinke at http://hdl.handle.net/10945/42645.
3. "Control strategy: wind energy powered variable chiller with thermal ice storage," by R.A. Boonyobhas at http://hdl.handle.net/10945/44525. ⚓

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